R&D Investment Trends and the Role of Government

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The long run is not a problem—until you get there

Steps in R&D Policy Analysis:

(1) Demonstrate **importance** of the policy topic

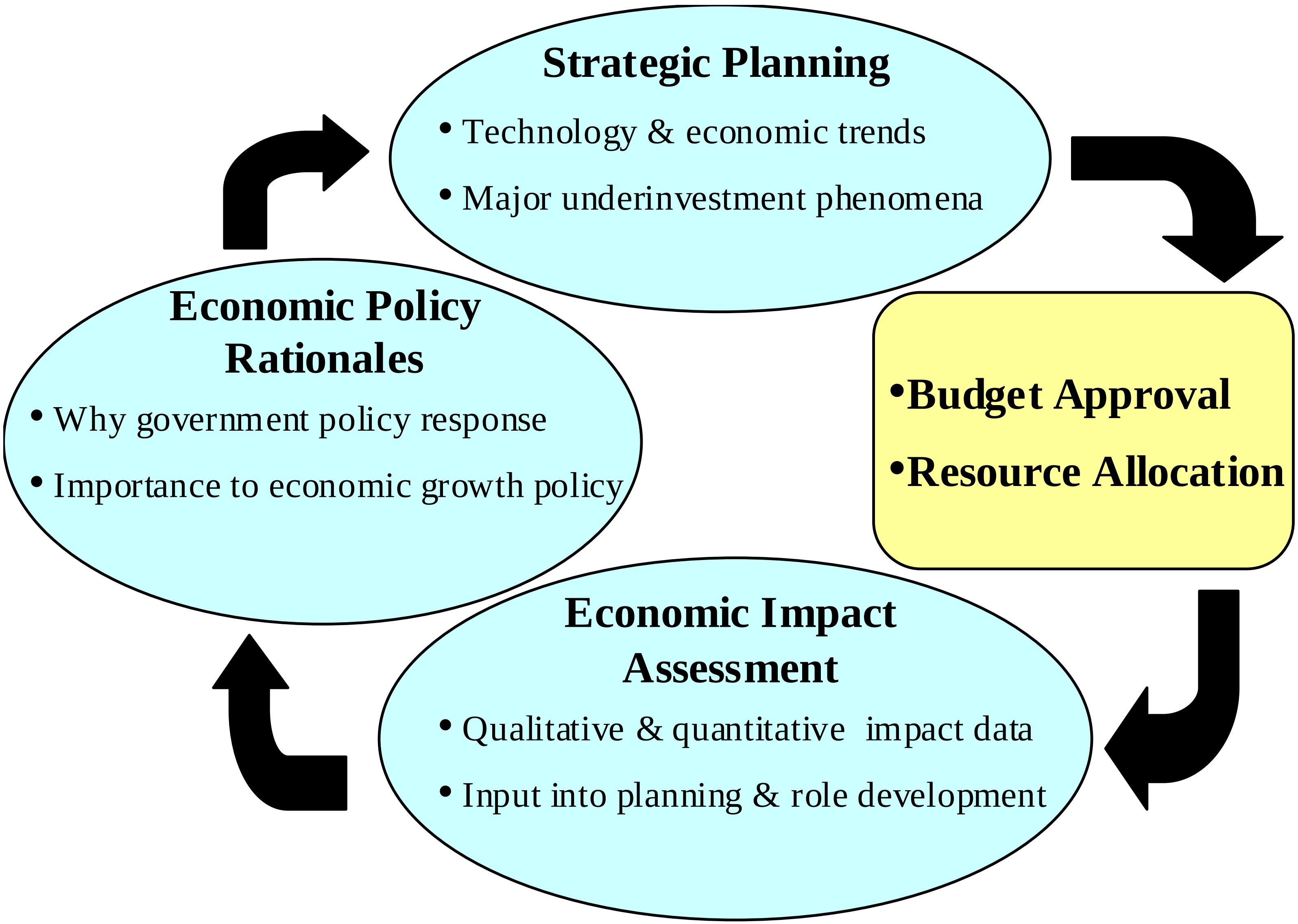
(2) Indicators of long-term **underinvestment in technology**
- Low rates of productivity growth
- Persistent trade deficits
- Declining corporate profits
- Low rates of innovation

(3) **Causes of underinvestment** (market failure mechanisms)
- Excessive discounting
- Appropriability problems
- Market structure deficiencies
- Inadequate infrastructure

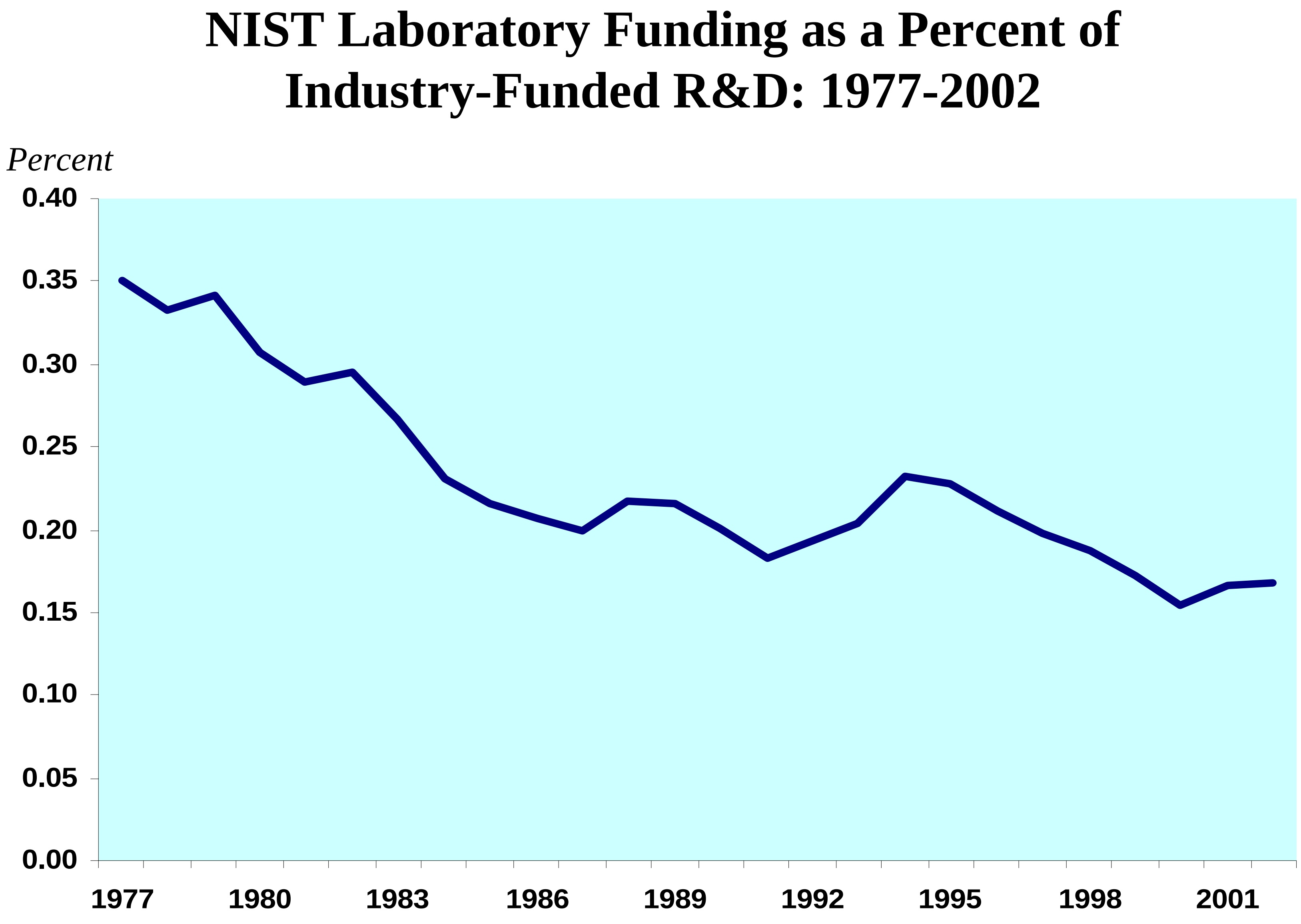
(4) Estimation of **underinvestment in R&D**?
- Aggregate R&D investment trends
- R&D investment by technology element/phase

(5) **Policy Responses** (match policy instruments with underinvestment phenomena and required resources)

Economic Tools for Policy Analysis



Policy Issue



Source: National Science Foundation; NIST Budget Office

Technology's Impact on Economic Growth

1) Accounts for *one-half of output (GDP) growth* in all industrialized nations (except Canada)

2) Accounts for *three-quarters of productivity growth*

3) Increase in U.S. productivity growth that began in the mid-1990s is *entirely due to technology* investments.

4) Productivity advantage of the U.S. economy over other OECD countries accounts for *three-quarters of the per capita income gap*

5) Rate of return to basic science is about *three times* that for applied R&D, which, in turn, has *twice* the return on physical capital

How High-Tech is the U.S. Economy?

- **High-Tech Sector:**
  - Electronics
  - Pharmaceuticals
  - Communication Services
  - Software and Computer-Related Services
- **Accounts for 7 – 10 percent of GDP**
- **Message:** The other 90+ percent of the economy is susceptible to market share erosion and decline

How High-Tech is the U.S. Economy?

Geographic Concentration:

- Six states account for almost one-half of all R&D
- Ten states account for almost two-thirds of all R&D
- **Message:** The remaining 40 states are not a high-tech economy

How High-Tech is the U.S. Economy?

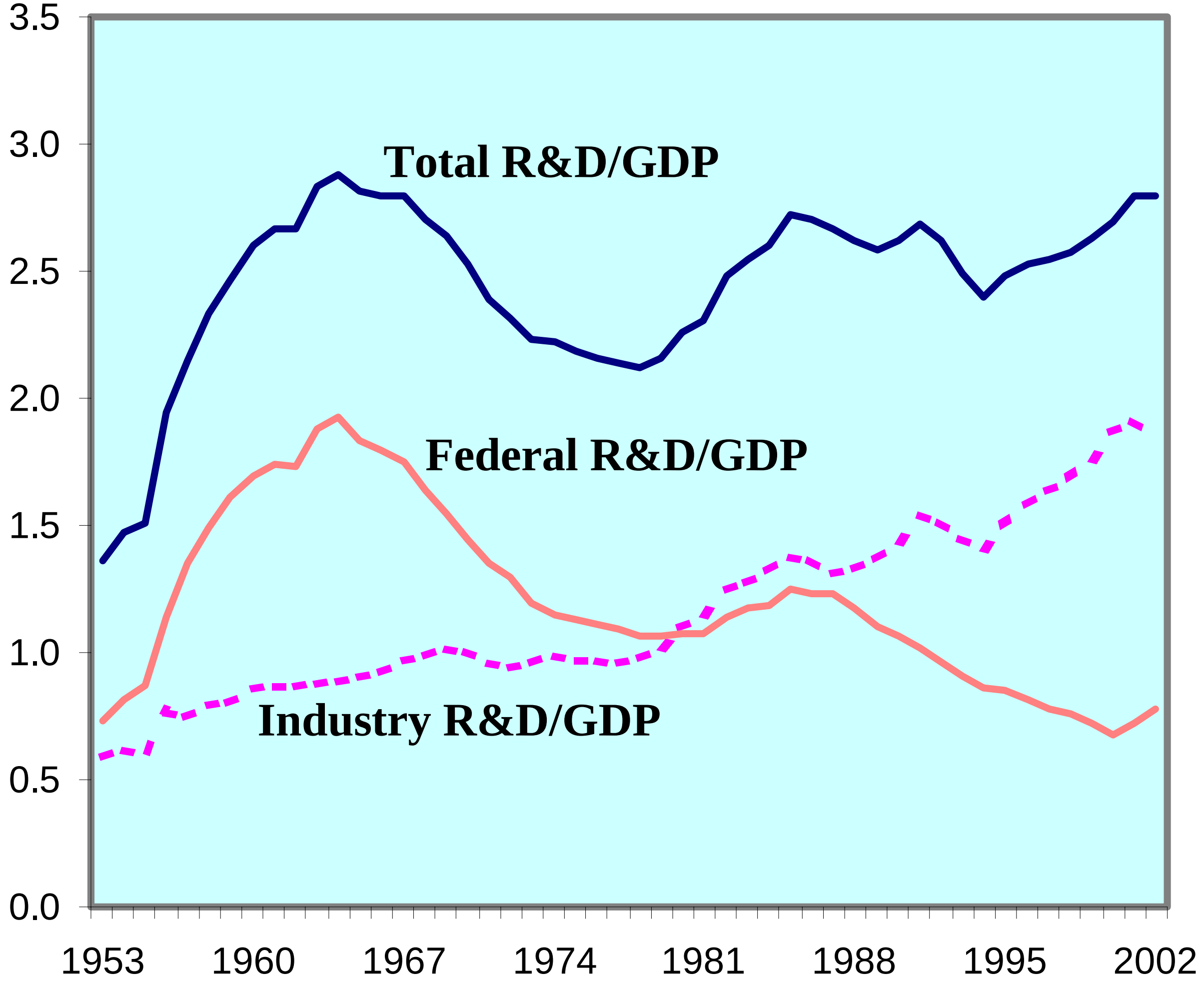
Geographic Distribution of U.S. R&D Performance

State	% of Population	% of National R&D
California	12.0	20.7
Michigan	3.5	8.1
New York	6.7	6.1
Texas	7.4	5.4
Massachusetts	2.3	5.3
Pennsylvania	4.4	4.6
New Jersey	3.0	4.6
Illinois	4.4	4.2
Washington	2.1	3.6
Maryland	1.9	3.5
Total	**47.7**	**66.1**

Source: National Science Foundation

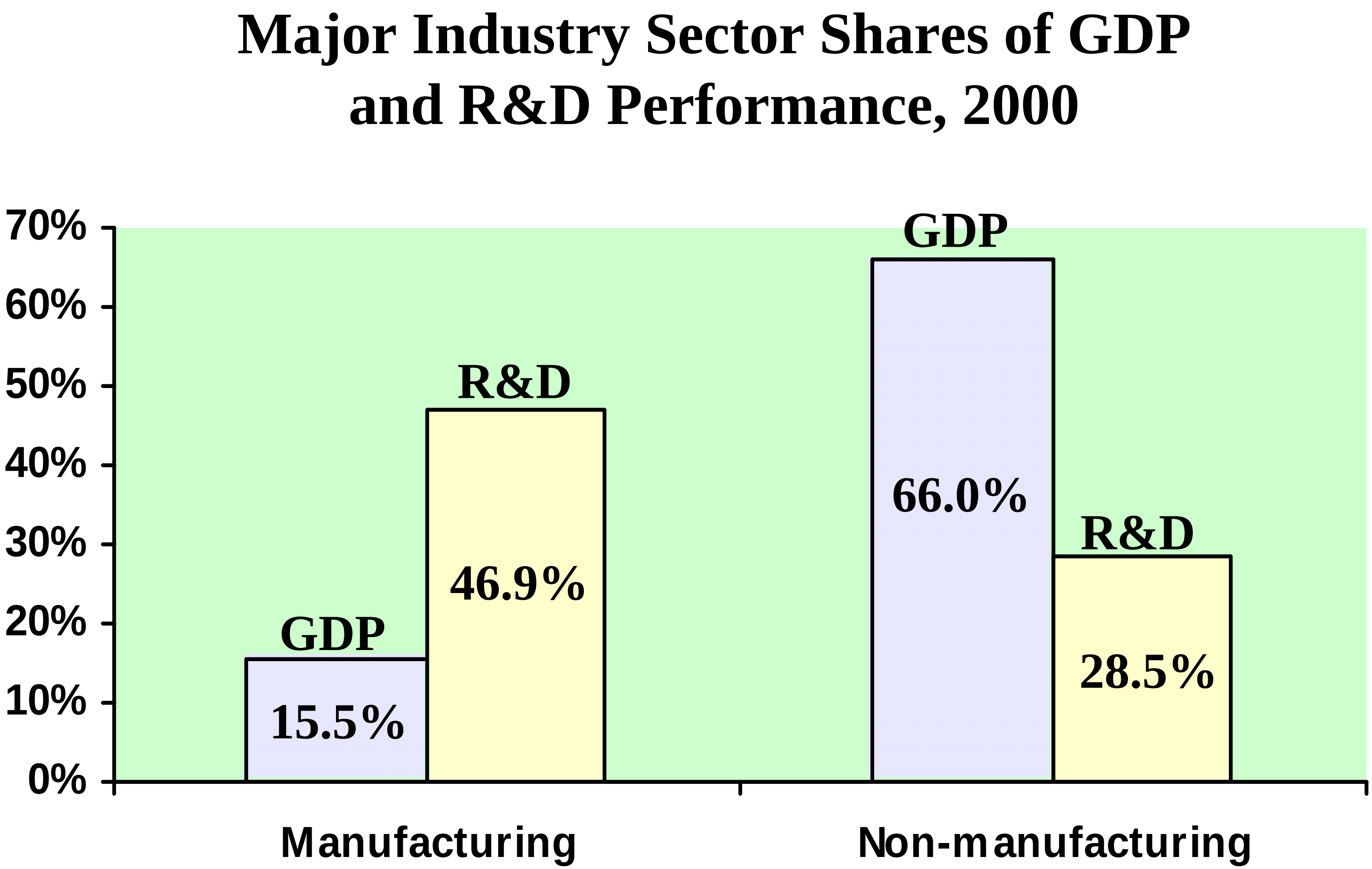
How High-Tech is the U.S. Economy?

R&D Intensity: Funding as a Share of GDP, 1953-2002



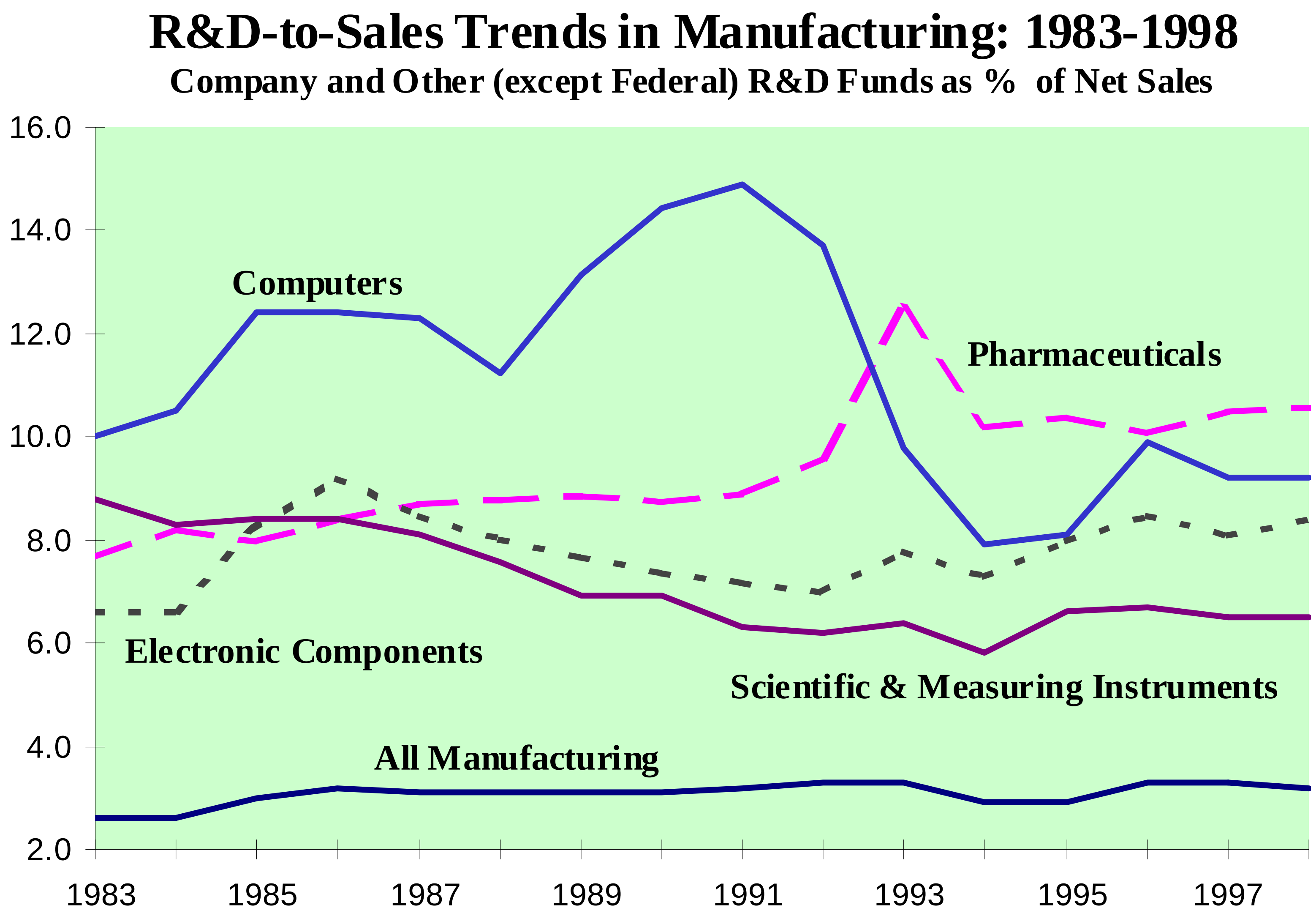
Source: National Science Foundation

How High-Tech is the U.S. Economy?



Source: Bureau of Economic Analysis, National Science Foundation

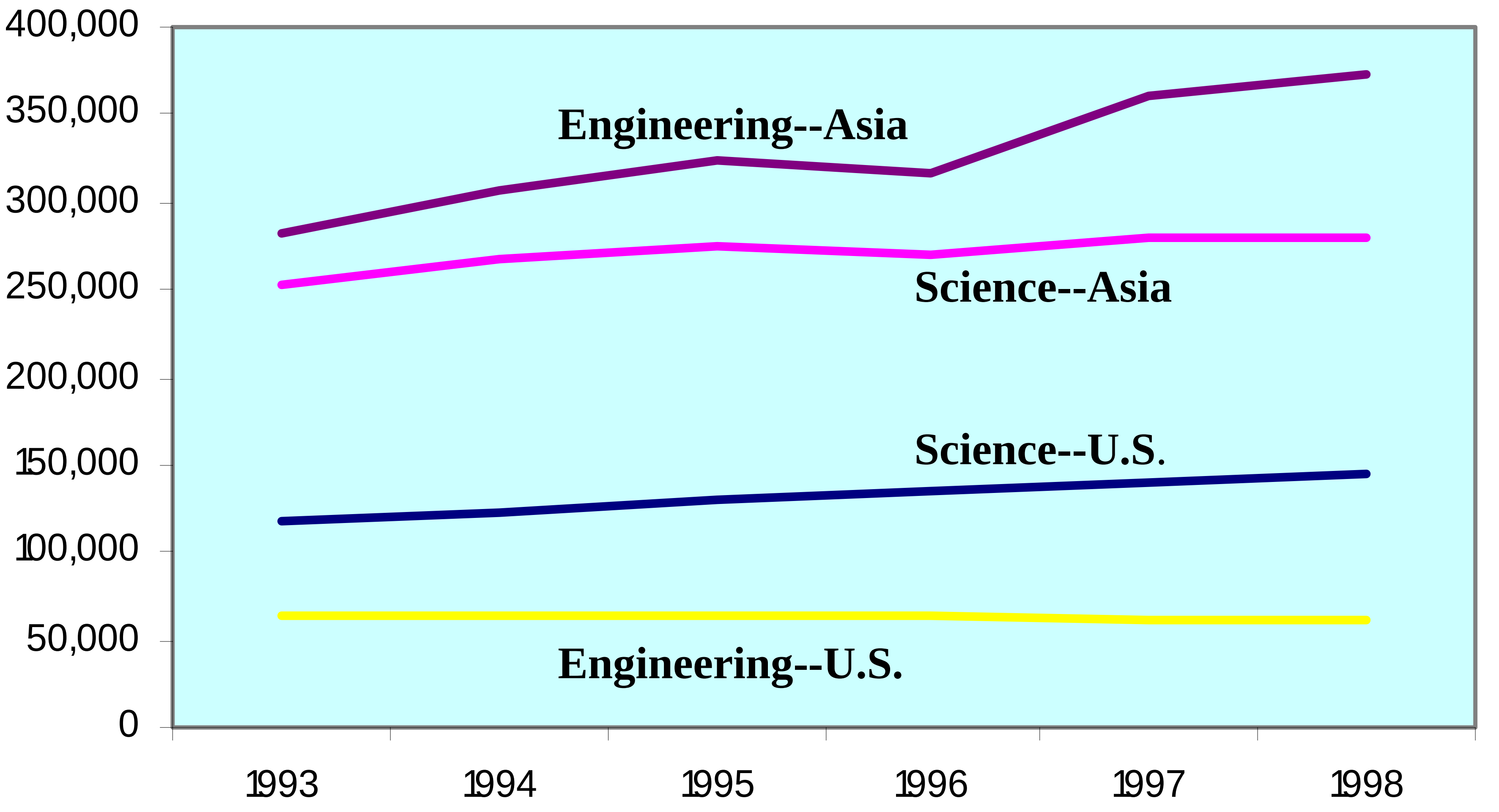
How High-Tech is the U.S. Economy?



Source: National Science Foundation, *National Patterns of R&D Resources*: *Early Release Tables, 2000*

How High-Tech is the U.S. Economy?

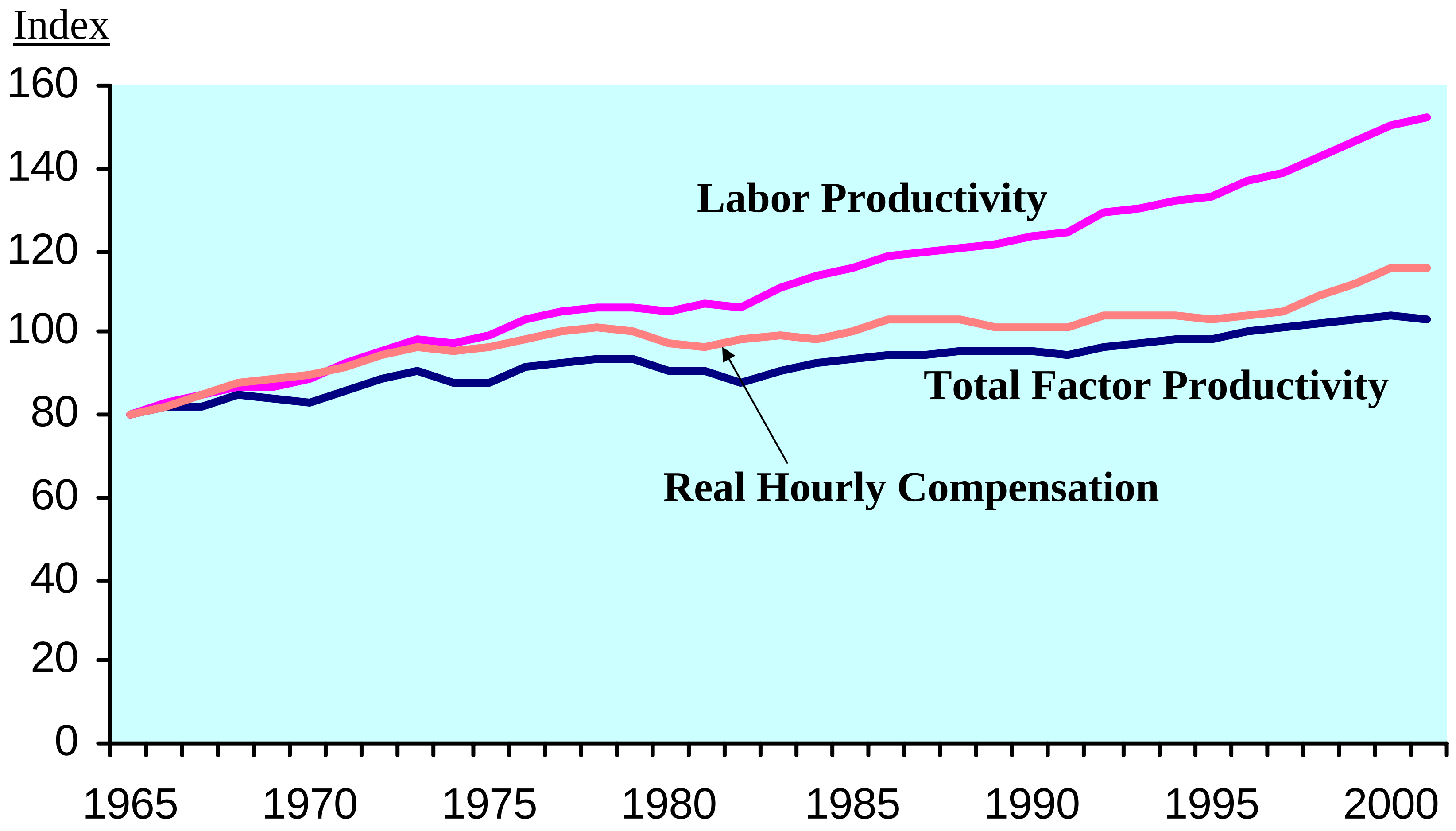
Bachelor's S&E Degrees in the United States and Asia: 1993-1998



Note: Asian data include China, India, Japan, South Korea, and Taiwan

How Has the "High-Tech" Economy Performed?

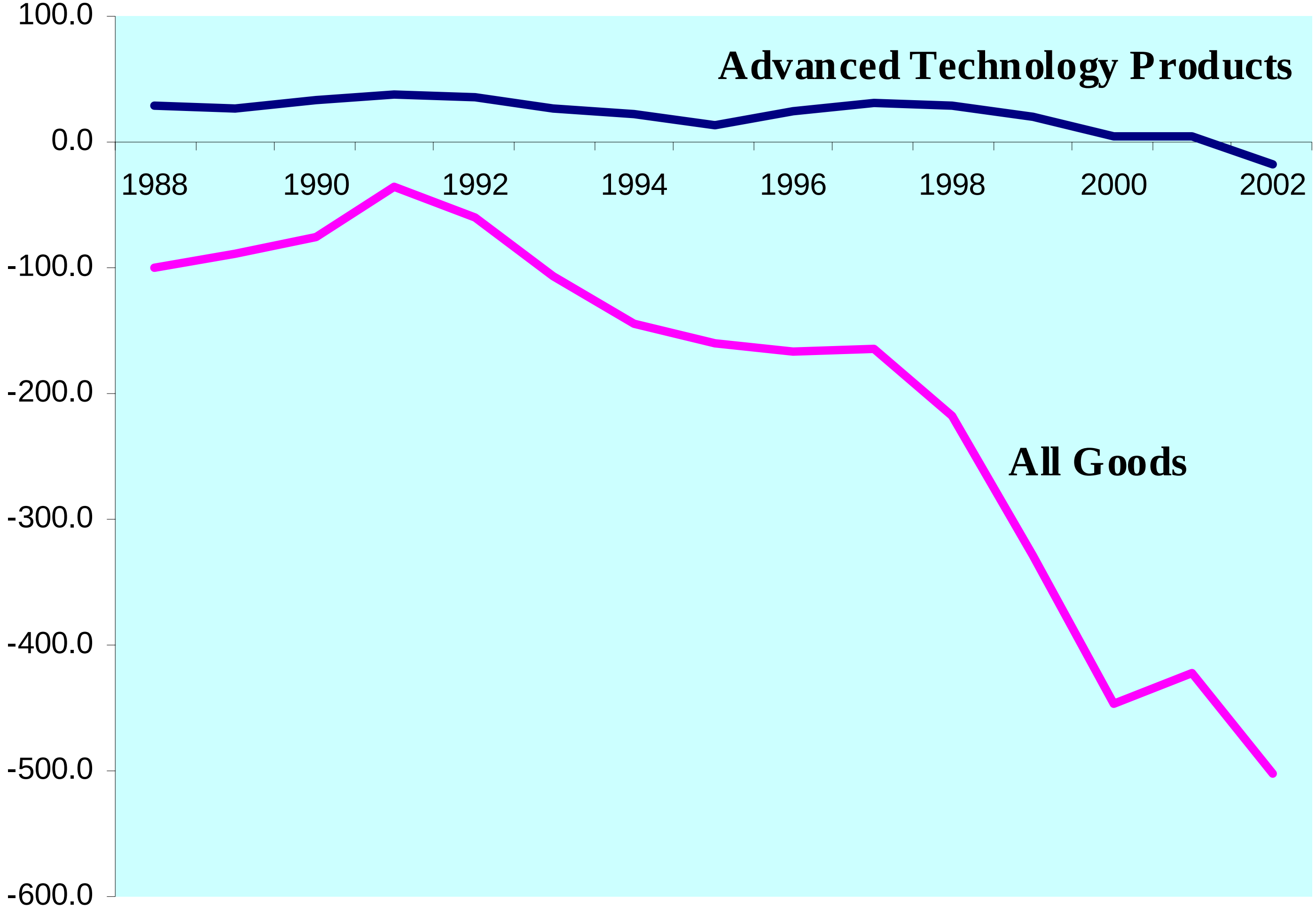
Long-Term Trends in Productivity and Income: 1965-2001



Source: Bureau of Labor Statistics

How Has the “High-Tech” Economy Performed?

U.S. Trade Balances for High-Tech Products and All Goods 1988-2002 (in $billions)

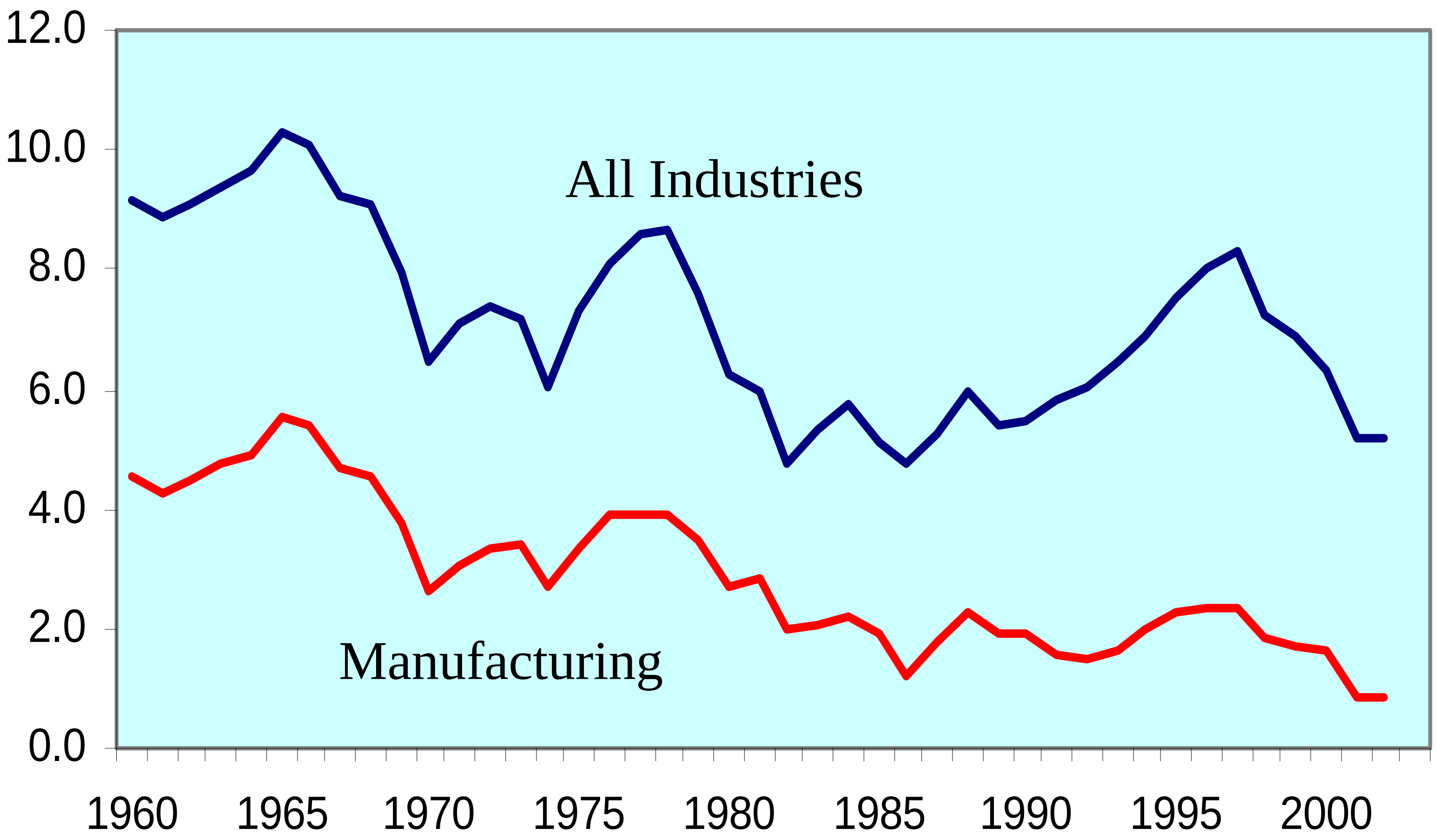


Source: Census Bureau, Foreign Trade Division

How Has the "High-Tech" Economy Performed?

Domestic Corporate Profits as a Percent of GDP 1960–2002

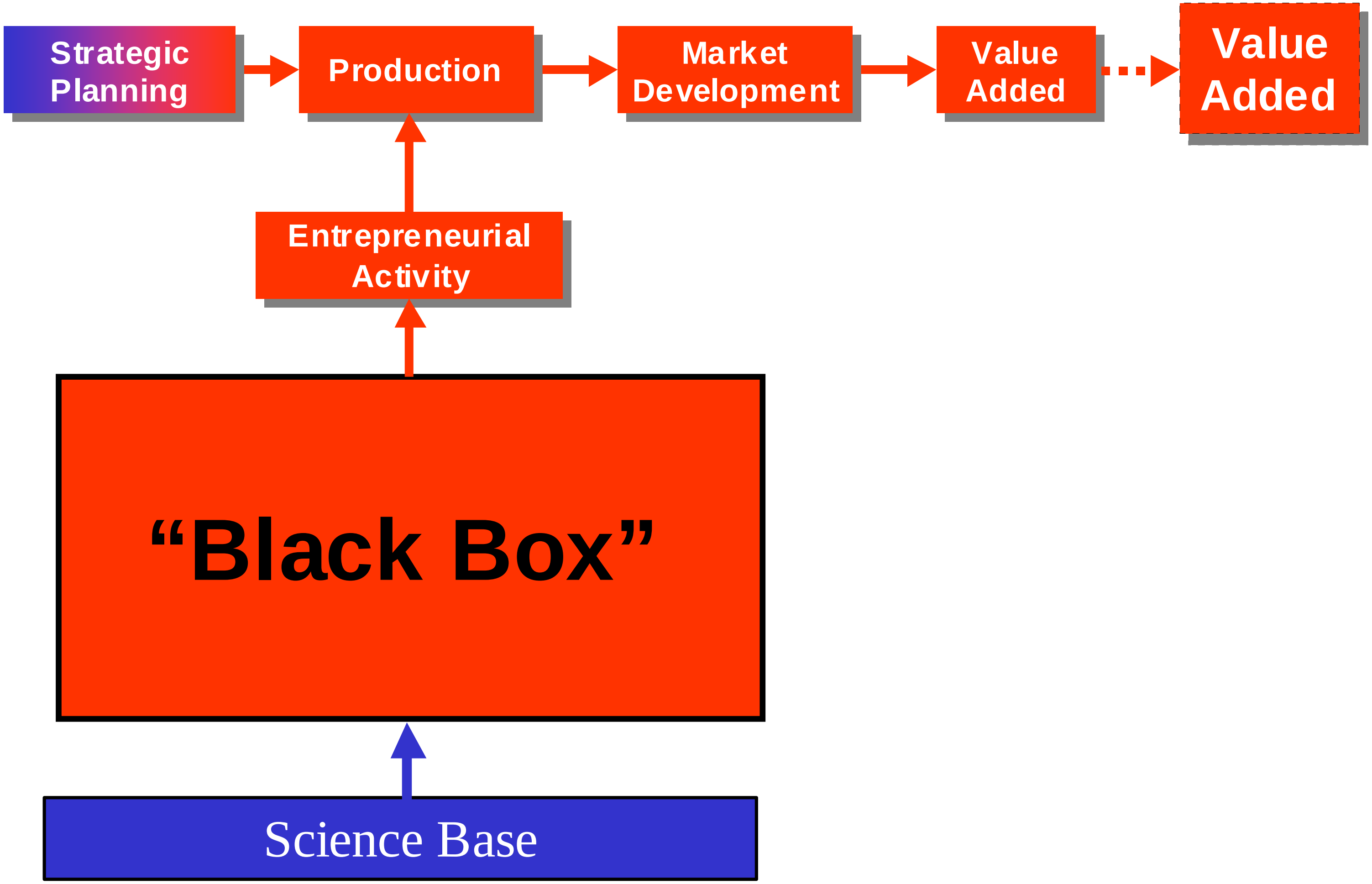
(Before Taxes and with Inventory Valuation and Capital Consumption Adjustments)



Source: Bureau of Economic Analysis

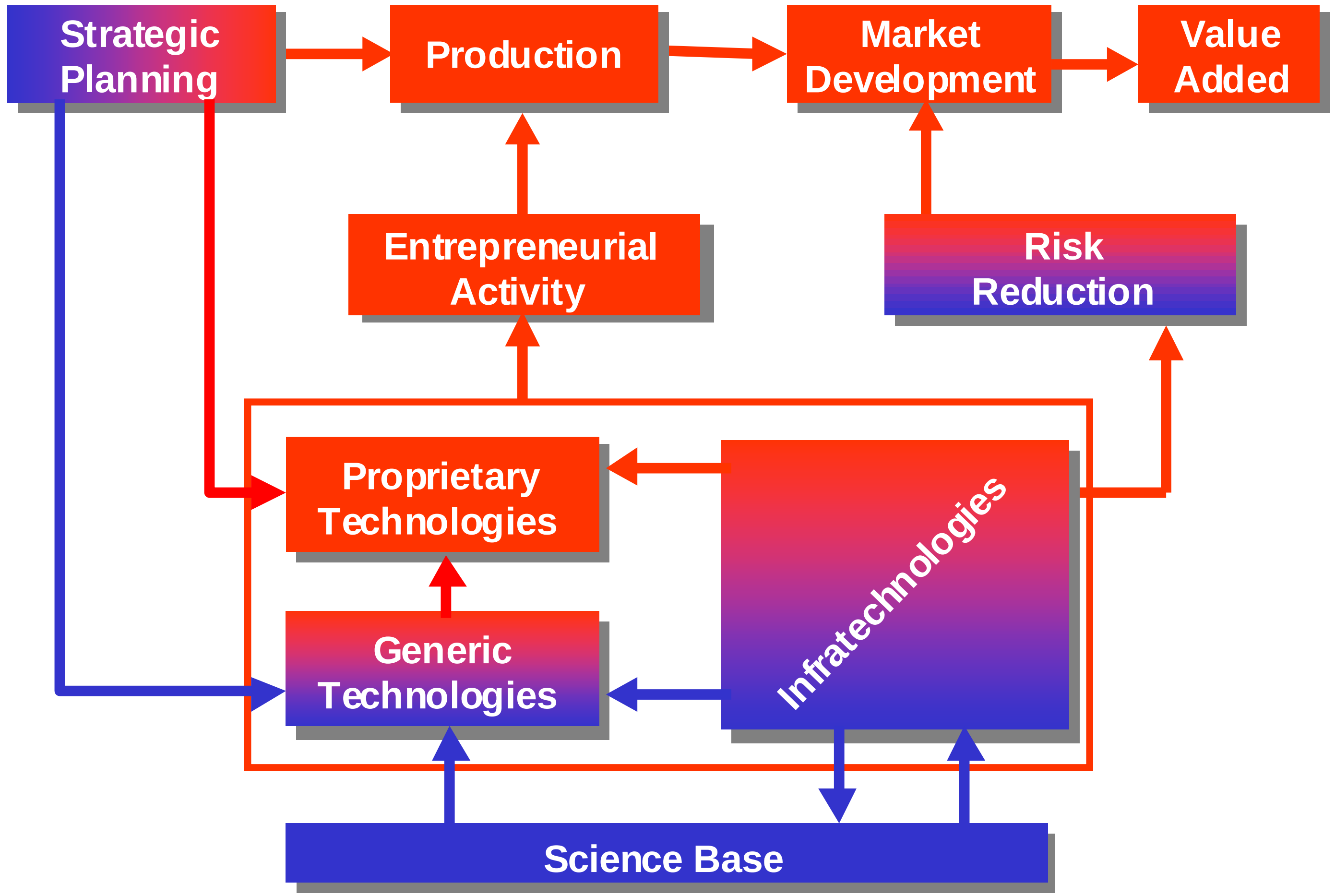
R&D Underinvestment Analysis

“Black Box” Model of a Technology-Based Industry



R&D Underinvestment Analysis

Economic Model of a Technology-Based Industry



Source: G. Tassey, *The Economics of R&D Policy* Quorum Books, 1997, p. 70

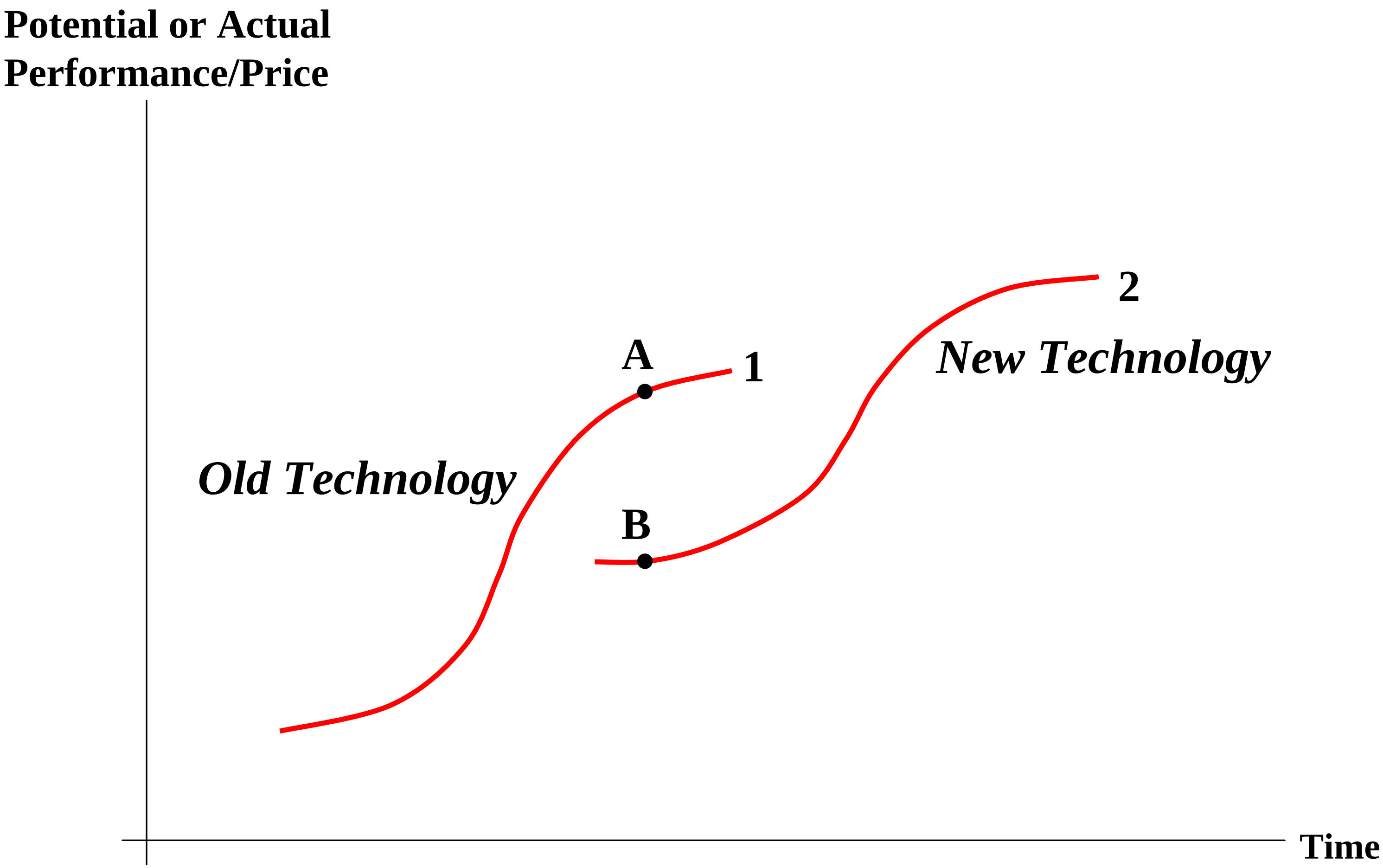
R&D Underinvestment Analysis

Application of the Technology Model: Biotechnology

Science Base	Infratechnologies	Generic Technologies: Product	Generic Technologies: Process	Commercial Products
Genomics	bioinformatics	antiangiogenesis	cell encapsulation	coagulation inhibitors
Immunology	biospectroscopy	antisense	cell culture	DNA probes
Microbiology/ virology	combinatorial chemistry	apoptosis	DNA arrays/chips	inflammation inhibitors
Molecular and cellular biology	DNA chemistry, sequencing, and profiling	bioelectronics	fermentation	hormone restorations
Nanoscience	Electrophoresis	biomaterials	gene transfer	nanodevices
Neuroscience	Fluorescence	biosensors	immunoassays	neuroactive steroids
Pharmacology	gene expression analysis	functional genomics	implantable delivery systems	neuro-transmitter inhibitors
Physiology	magnetic resonance spectrometry	gene delivery systems	nucleic acid amplification	protease inhibitors
Proteomics	mass spectrometry	gene testing	recombinant DNA/genetic engineering	vaccines
	nucleic acid diagnostics	gene therapy	separation technologies	
	protein structure modeling/analysis techniques	gene expression systems	transgenic animals	
		monoclonal antibodies		
		pharmacogenomics		
		stem-cell		
		tissue engineering		

R&D Underinvestment Analysis

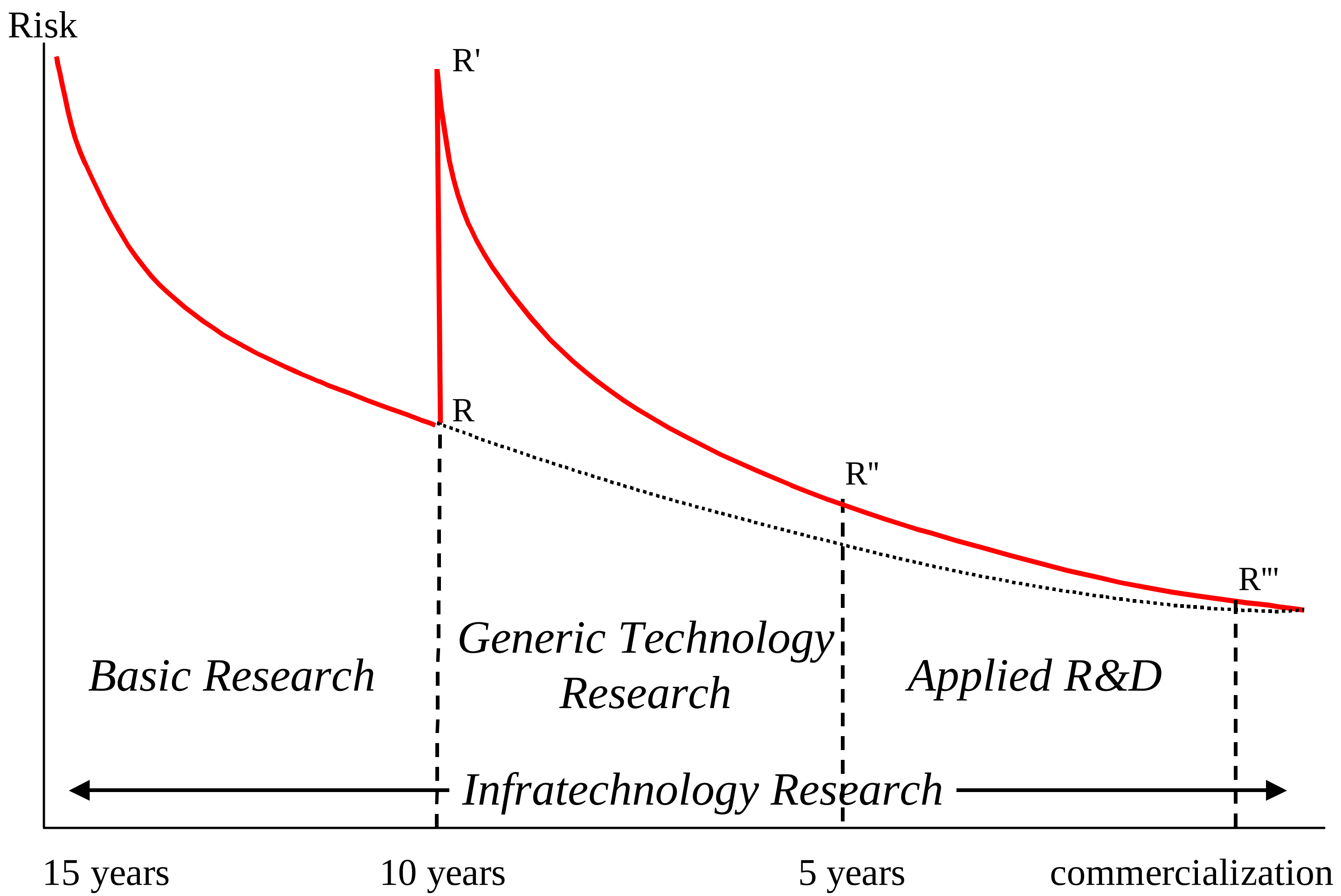
Transition Between Two Technology Life Cycles



Source: Gregory Tassey, *The Economics of R&D Policy*, Quorum Books, 1997, Chap. 7

R&D Underinvestment Analysis

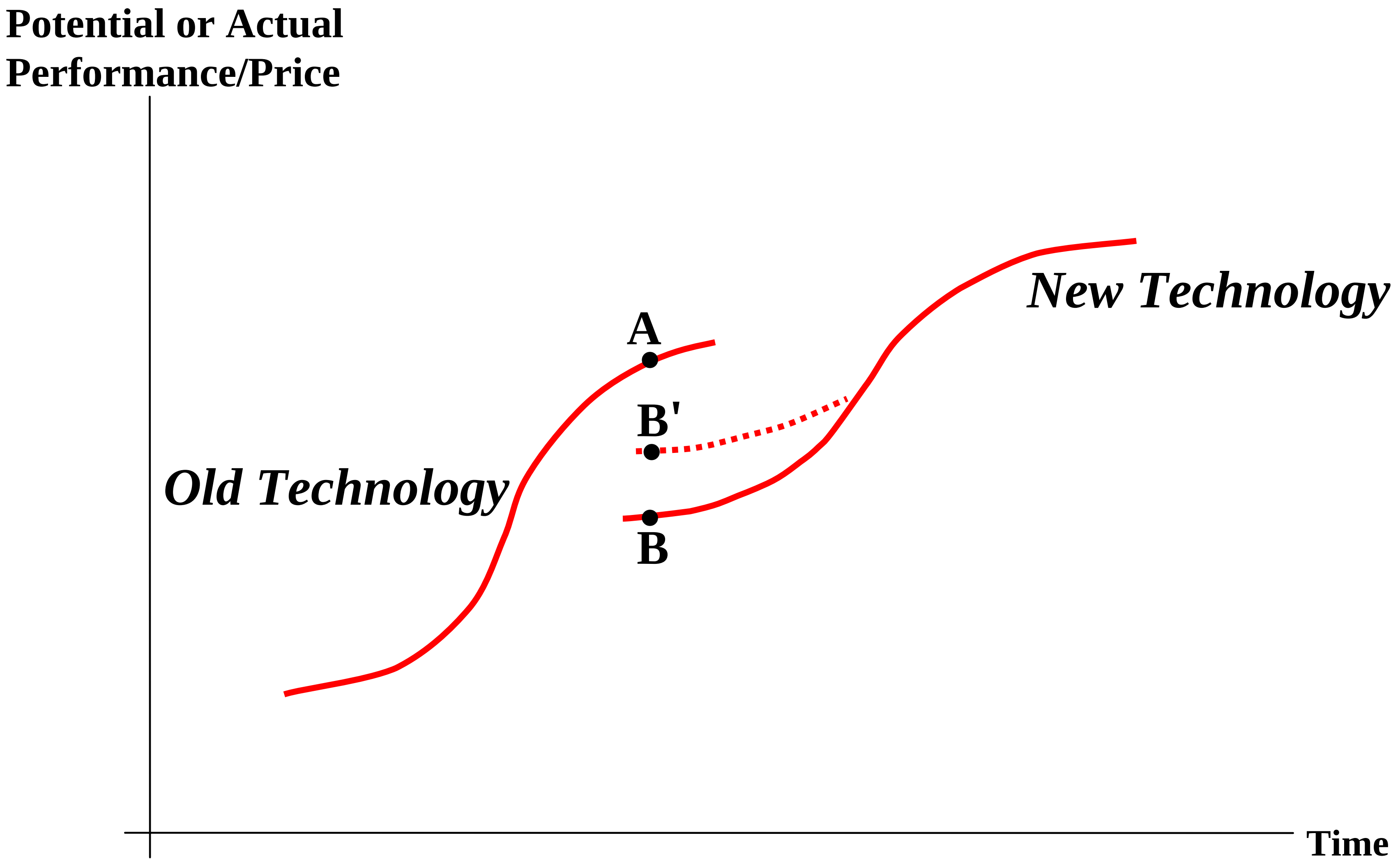
Risk Reduction Over a Technology Life Cycle



Source: Gregory Tassey, *The Economics of R&D Policy*, Quorum Books, 1997, Chap. 7

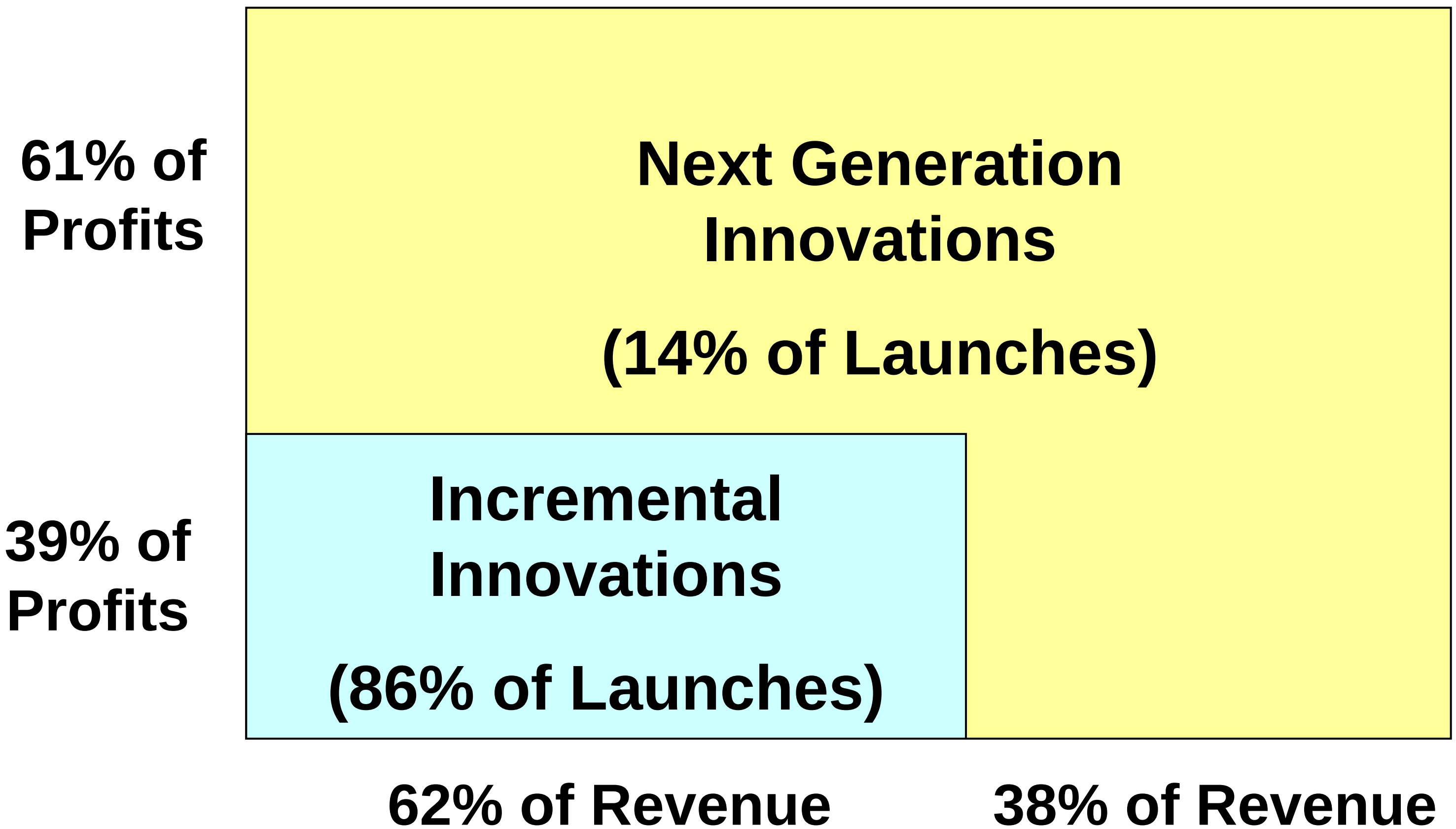
R&D Underinvestment Analysis

Life Cycle Evolution: Generic Technology



How Important is the Composition of R&D?

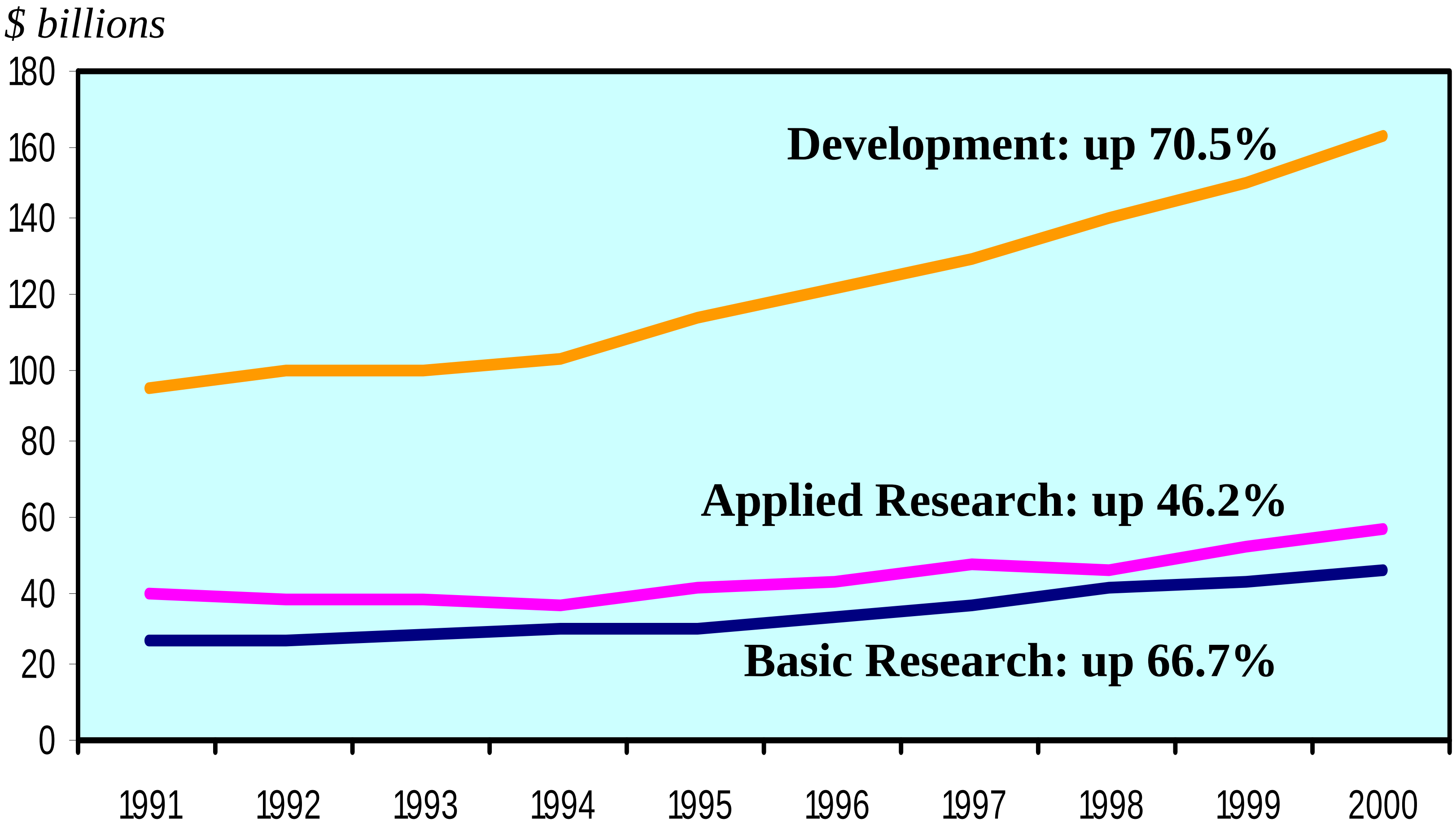
Profit Differentials for Major and Minor Innovations



Source: W. Chan Kim and Renee Mauborgne, “Value Innovation: The Strategic Logic of High Growth”, *Harvard Business Review*, 1997

How Important is the Composition of R&D?

Trends in U.S. R&D by Major Phase of R&D, 1991-2000



Source: National Science Foundation, *National Patterns of R&D Resources, 2000*

How Important is the Composition of R&D?

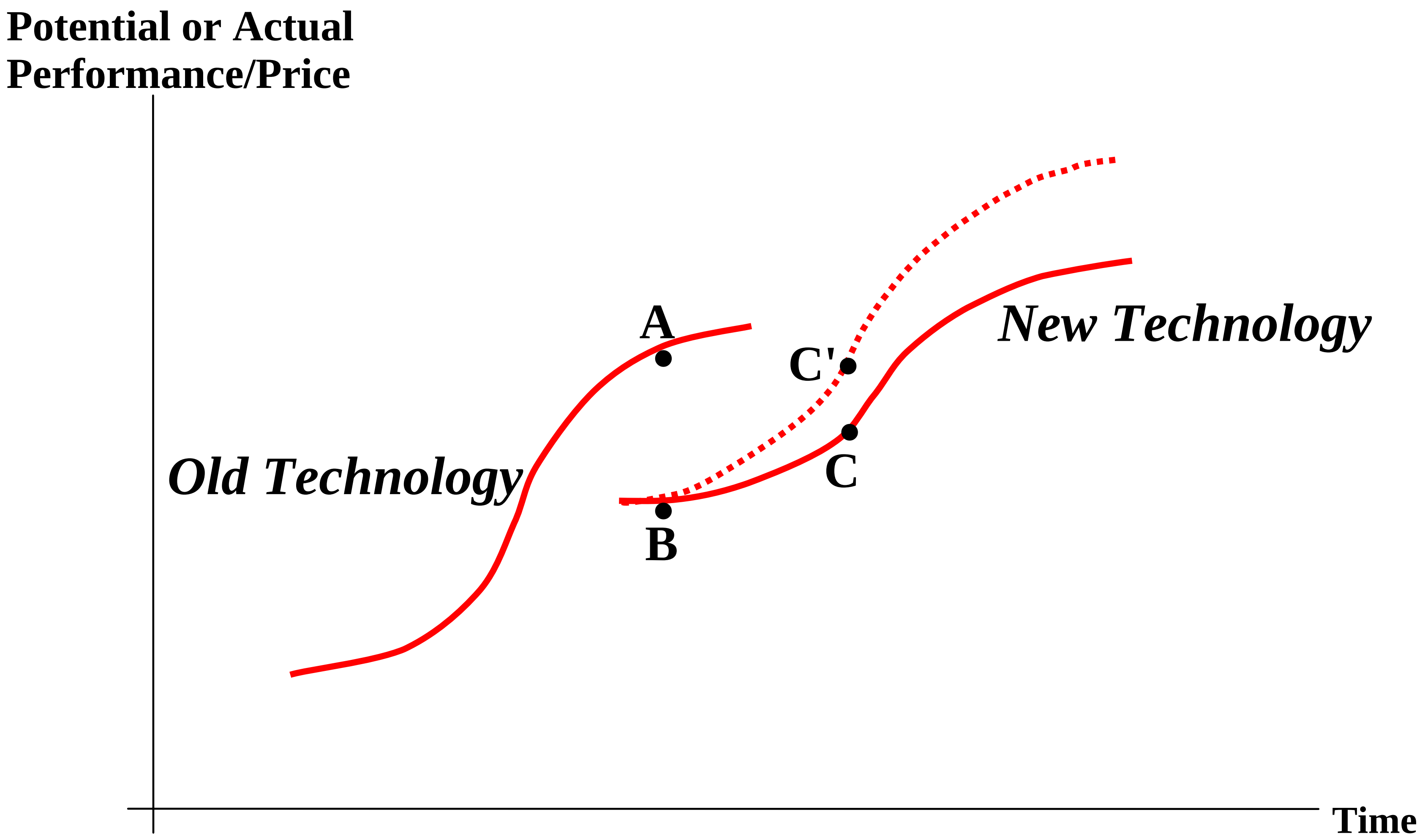
IRI "Sea Change" Index: Member Firms' Annual Planned Investments

Forecast Year	Directed Basic Research	New Business Projects
1993	**-26**	**+18**
1994	**-26**	**+18**
1995	**-19**	**+31**
1996	**-6**	**+39**
1997	**-26**	**+28**
1998	**-14**	**+24**
1999	**-23**	**+31**
2000	**-9**	**+34**
2001	**-21**	**+44**
2002	**-13**	**+30**
2003	**-21**	**+7**
2004	**-17**	**+1**

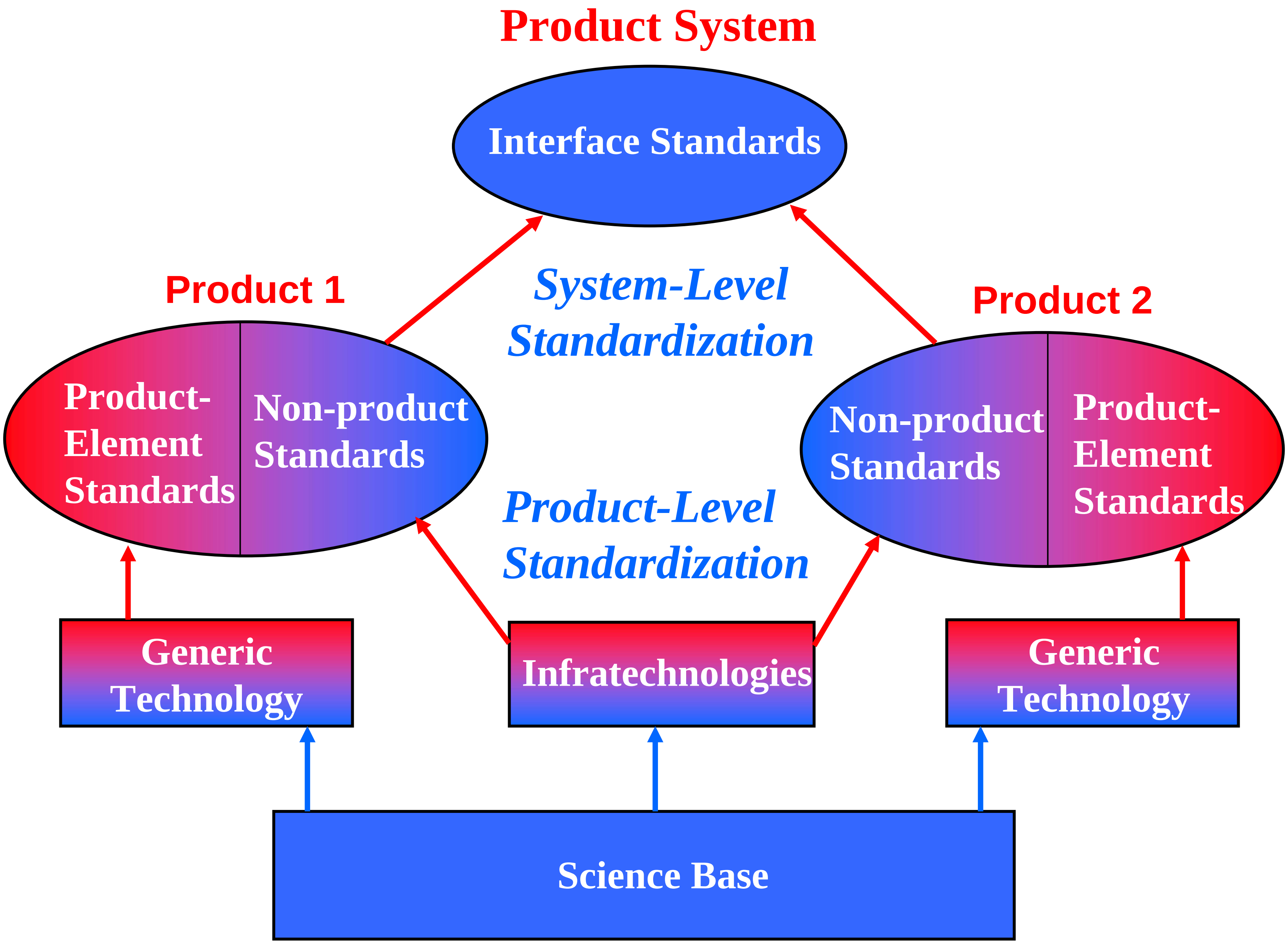
Source: Industrial Research Institute's annual surveys. The Sea Change Index is calculated by subtracting the percent of respondents reporting a planned decrease in the particular category of R&D spending from the percent planning an increase of greater than 5 percent.

R&D Underinvestment Analysis

Life Cycle Evolution: Infratechnology



How Important Are Infratechnologies & Standards?



How Important Are Infratechnologies & Standards?

Recent Retrospective Economic Impact Studies: Outputs and Outcomes of NIST Laboratory Research			
Industry/Project	**Output**	**Outcomes**	**Measure**
Chemicals: Standards for sulfur in fossil fuels (2000)	• Measurement methods • Reference materials	• Increase R&D Efficiency • Increase productivity • Reduce transaction costs	IRR: 1,056% BCR: 113 NPV: $409M
Semiconductors: Josephson volt standard (2001)	• Measurement methods • Reference materials	• Increase R&D efficiency • Enable new markets	IRR: 877% BCR: 5 NPV: $42M
Communications: Data encryption standard (2001)	• Standard (DES) • Conformance test methods	• Accelerate new markets • Increase R&D efficiency	IRR: 270% BCR: 58–145 NPV: $345M–$1.2B
Communications: Role-based access control (2001)	• Generic technology • Reference models	• Enable new markets • Increase R&D efficiency	IRR: 29–44% BCR: 43–99 NPV: $59–138M
Energy: Gas mixture standard for regulatory compliance (2002)	• Standard (NTRM)	• Increase productivity • Reduce transaction costs	IRR: 221–228% BCR: 21–27 NPV: $49–63M
Manufacturing: Product design data standard (2002)	• Standard (STEP) • Conformance test methods/facilities	• Increase R&D efficiency • Reduce transaction costs	IRR: 32% BCR: 8 NPV: $180M

IRR=Internal (Social) Rate of Return, BCR=Benefit-Cost Ratio and NPV=Net Present Value.

Microeconomic Analysis for Strategic Planning

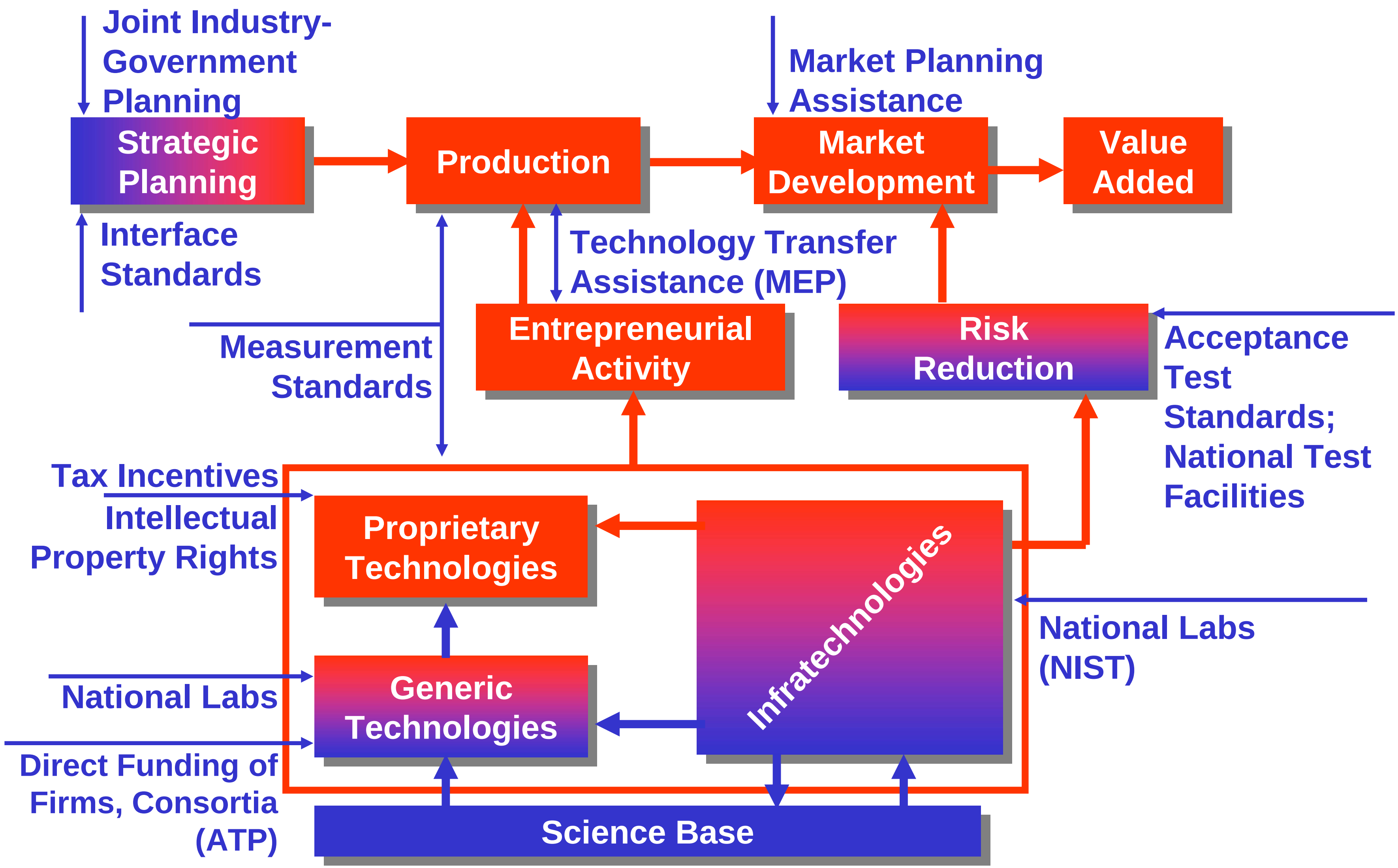
Recent Prospective Economic Studies of Costs due to Inadequate Technology Infrastructure			
Focus of Study	**Industries Covered**	**Infrastructure Studied**	**Estimated Annual Costs**
Interoperability costs (1999)	• Automotive supply chain	• Product design data exchange	$1 billion
Deregulation (2000)	• Electric utilities	• Metering • Systems monitoring/control	$3.1–$6.5 billion
Software testing (2002)	• Transportation equipment • Financial services	• All stages of the testing cycle	$60 billion
Interoperability costs (in progress)	• Transportation equipment • Electronics supply chains	• Business data exchange: demand, production, inventory, procurement, & distribution	
Medical testing (in progress)	• Laboratories (calcium)	• Quality of measurement assurance	$0.4–$1.3 billion
Service sector R&D (in progress)	• Telecommunications • Software • Financial • RD&T	• R&D classifications • Manufacturing interface	

Costs of Inadequate Software Testing Infrastructure

Industry Coverage	Annual Cost	Potential Economic Benefits
Transportation Equipment and Financial Services	$5.85 B	$2.10 B
U.S. Economy	$59.5 B	$22.2 B

Source: RTI International, *The Economic Impacts of Inadequate Infrastructure for Software Testing* (NIST Planning Report 02-3)

Technology-Based Policy Options



R&D Policy Options

If the R&D investment problem is

“Inadequate science base”:

- ***Fund basic research*** at adequate scope and depth

“Inadequate amount of R&D”

- ***Provide tax incentives*** (e.g., R&E tax credit) sufficient to raise expected rates of return above corporate hurdles

“Distorted composition of R&D”

- ***Co-fund generic technology research*** (e.g., DARPA/ATP model) to create attractive “real options” for portfolio of emerging technologies with economic growth potential

R&D Policy Options

How much R&D?

- If all manufacturing industries invested at the same rate as the high-tech segment, this sector's R&D would increase from $130B to roughly $400B
- If the Federal Government spent as much on *all areas of science combined* as it did just on health research in FY03, its R&D budget would have been roughly $4B larger
- Several economic studies (Griliches; Jones and Williams) indicate that national R&D should be increased by a factor of between two and four
- If NIST lab funding was at same proportion of industry-funded R&D in 2002 as 25 years earlier, budget would have been $677 million (roughly double)

R&D Policy Options

"Sooner or later, we sit down to
a banquet of consequences"

– Robert Louis Stevenson